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Globes. 1829

Latitude et longitude - Instruments
1829

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A
TREATISE

ON

COSMOSPHERICALLY MOUNTED

TERRESTRIAL AND CELESTIAL GLOBES,

FOR

Self-instruction and for Schools.

WITH AN

APPENDIX,

ON

THE USE OF COSMOSPHERICALLY MOUNTED GLOBES, OF AN
ORBOGRAPH, OF A LOXODROMOGRAPH, AND OF
A SPHEROMETER,

INSTRUMENTS FOR CALCULATING
THE LATITUDE AND LONGITUDE AT SEA.

BY

DR. W. MULLER,

MAJOR OF THE ROYAL HANOVERIAN ENGINEERS.

LONDON:
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A TREATISE

ON

COSMOSPHERICALLY MOUNTED TERRESTRIAL AND CELESTIAL GLOBES.

INTRODUCTION.

Sec. 1.—THE common manner of mounting a terrestrial and a celestial globe, limits the use of both to the solving of a few of the most common problems, not mentioning the inconveniences experienced in applying them for explaining some subjects or other of geography and astronomy. And the unnatural position of a part of the stand of a globe, mounted in the common manner, or of a plane or ring of wood round their surface, the centre of which is to be in the centre of the globe, and which is to show the horizon corresponding to any part of their surface, is the greatest objection; as, after adjusting the horizon to a certain point, an idea of a motion of the globe will put every part out of its relative and true position.

II. The free suspension of cosmospherically mounted globes allows them, however, to swivel free round their centre in any direction required, while they avoid the unnatural representation of the horizon, which, if adjusted to any point of the surface of a cosmospherically mounted globe, will swivel round with it, and allow the solving of problems in astronomy and geography, which hitherto were considered impracticable for common mounted globes.

III. Comparing now, in all directions round their centre, free swivelling, or cosmospherically suspended globes, to the common bulky, and in some respects unnaturally mounted globes, it need only be observed, that the former become interesting, and will be of a greater real use in explaining, according to nature and truth, such parts of the system of the universe, as are to be represented by them.

IV. For self-instruction and for schools, the cosmospherically mounted globes will be found of the greatest use to those wishing to become acquainted with, or of viewing a true representation of the natural parts of the universe; and will also inspire the mind with the highest veneration for the great Power which made and supports the globe which we inhabit, having about 25,000 miles in circumference, and on the surface of which a town larger than London, or of 100 square miles, occupies not one 10,000,000,000th part, and which globe revolves in proportionate times, with a certain velocity, at a distance of 95,000,000 miles (a length which a gun-ball shot from a cannon, in its swiftest course, would not be able to pass in twenty-four years) round the sun, a body above one million times as large as our earth, and from which we receive warmth and light.

V. The labour of acquiring a true knowledge of the universe, will soon be rewarded by the facility which cosmospherically suspended globes afford in attaining a scientific acquaintance of the most admired subjects which may come to our knowledge during the time of our life.

VI. The satisfaction and improvement of mind which we derive from an acquaintance with our earth, and its motions, will inspire us with veneration for its Maker; but this will become greater, if we consider that ten other (some larger, some smaller,) bodies like our earth revolve round the sun, similarly to our globe, the farthest in a distance of 1,800,000,000 miles from the sun; and next, that round these bodies (called planets) others (named satellites) again move; and that in immeasurable space, at an inconceivable great distance from us, again other numberless bodies, called stars, like our sun, and most likely with planets appertaining to each of them, form the starred sky.

VII. Of the existence of the planets of our solar system, and of their motion round the sun, and the revolutions of their satellites, we have sufficient proof; and the fixed stars we see and admire daily, without being able to ascertain their distance and number.*

II.—DESCRIPTION OF COSMOSPHERICALLY MOUNTED GLOBES.

Sec. 2.—I. A cosmospherically mounted terrestrial globe turns round two iron pins, the centre of which forms the south and north *pole* on the surface of the globe. From this, the southern and northern hemispheres take their denomination. An imaginary line, uniting the two poles, is the axis of our globe. The circle at an equal distance from each of the poles, round the globe, is the *equator;* it is divided into 360 degrees (like every circle), and these into minutes, 60 of which form a degree, &c.: and thus will each pole be 90 degrees from the equator.

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* In considering the proved existence of the universe, the first thought will be, what was the origin of the mentioned bodies, and what incomprehensibly omnipotent Power put and keeps them in their regular motion? And the mind being thus convinced of the existence of a surprising wonderfully high and great Power, may again enquire, Does not this power know the most secret of our actions, and the most secret of our thoughts?

II. An observer, or a place on our earth, is represented on a terrestrial globe by a pin in a small tube, fixed to the ring undivided, near the place where a semi-ring meets it. In the diametrically opposite part of the globe, or above the place of the observer's *antipodes*, is another small tube with a pin.

III. The place in the sky, above an observer, to which the other end of the pin points, is called the *zenith*, and the zenith of an antipode the *nadir*. Any circle described round the zenith or nadir in the vault of heaven, is called an *almucantarath;* and a circle, described in a similar manner round the pole of our earth, on its surface, and consequently parallel to the equator, is styled a *circle*, or a *parallel of latitude.*

IV. A plane through the large circle in the sky, equally distant from the zenith and the nadir, and a circle parallel to it, and equally distant from an observer on the earth, and his antipode consequently through the centre of our globe, is the *true horizon* of an observer. It is represented by a ring, with divisions, fixed to the above-mentioned ring, and semi-ring (II); the pins, marking an observer and his antipode, are equally, or 90 degrees, distant from the ring with divisions, and it lies in a plane through the centre of the terrestrial globe. That portion of the surface of our earth which is visible at sea from the place of an observer, is called the *visible horizon;* and a plane parallel to the true horizon, through the eye of an observer, is called his *natural horizon;* a representation of it is an *artificial horizon.* The horizon of the globe may be fixed, so as to correspond with any point marked by either of the pins near the intersection of the semi-ring, by the ring which is not divided, and screwing a notch and a nut round the axis of the globe, so as to keep the rings firm in their position, while the globe revolves round its axis.

V. Two of the circles of the parallels of latitude, at about

23.5 degrees distance from, and on each side of the equator, or those which mark the farthest part of the globe from the equator, in the zenith of which the sun sometimes comes, are called the *tropics:* the northern, *the tropic of the crab;* the southern, *the tropic of the goat.* At the same distance as the tropics from the equator, two other circles are supposed round the poles; they are called the *polar circles.*

VI. By these circles the earth is divided into two zones round the poles, two tropical zones, one at each side of the equator, and two temperate zones, each between a tropical and a polar zone.

VII. Formerly there existed a habit of representing a large circle round the globe, which had an inclination of about 23.5 degrees on the equator: it is called the *ecliptic;* but, being of no use, it only causes confusion, particularly if blotted with colours, and is better left out; but, instead of it, a calendar, showing the sun's declination and place in the ecliptic for every day during four years, or an improved *analemma,* for every day of a mean year, for a certain place, or a common analemma, is very useful and necessary for a terrestrial globe.

VIII. A large circle through both the poles of the earth, and a place on its surface, is a *meridian.* A part of it may be traced on the surface of the earth for any place. The sun will, at noon, be in the direction of this line. A similar line may be supposed on the true horizon of a place; one end of it lies in the direction of the sun at noon, one to the south and the other to the north. A perpendicular upon the middle of this line, in the true horizon, points to the right (from the south), to the east, and in the opposite direction to the west. These four points are called the *cardinal points.* Between them, generally, 28 others, forming 32 points in all, are supposed, as is shown on every compass.

IX. The distance of a place from the equator, counted in degrees and smaller parts on a meridian, is its *latitude;* and the distance on the equator, counted in degrees, minutes, &c. from the intersection of a first meridian to that of another meridian with the equator, is the *longitude* of a place.

X. The earth turning once every 24 hours round its axis, or 360 degrees of the equator, passing meanwhile under a certain fixed point in the sky, shows that the longitude may be counted in degrees or hours, taking $\frac{360}{24}$, or 15 degrees equal to one hour, 15 minutes of an arc equal to one minute of time, &c. A part of the equator, between the intersections of two meridians, may therefore be measured by degrees, &c. or hours, &c. counted on the equator. This quantity is always equal to the angle formed by two planes through both meridians, and it is called the *horary angle.*

XI. A large plane, through the zenith and nadir, in the sky, and consequently perpendicular on the horizon, and supposed to extend to the earth, forms the plane of vertical heights, or *altitudes.* An *altitude,* or a height of a celestial body above the horizon, is measured in degrees, minutes, &c. by an arc of a quadrant of altitude, from the horizon to the zenith, and lying in a plane of altitudes. This arc is, consequently, perpendicular on the horizon.

XII. The distance in degrees, minutes, &c. from the south point in the horizon to another point in the horizon, is called the *azimuth;* and the distance in degrees, minutes, &c. from the east or west point in the horizon to another point, is called the *amplitude.* Every point in an almucantarath has, therefore, another azimuth and another amplitude.

XIII. The *polar distance* is the complement of latitude, or the *co-latitude,* or the difference between 90 degrees and the latitude of a place; and the altitude of the pole, and the polar distance, being likewise 90 degrees, gives the altitude of the pole equal to the latitude of the place.

Sec. 3.—I. A cosmospherically suspended celestial globe has likewise on its surface two poles, in the centre of the two iron pins round which it turns: they represent the *poles of the world.* A line uniting both is *the axis of the world;* and a large circle, at equal distances from both poles, forms the *celestial equator,* generally called the circle of *right ascension.* It is parallel to the terrestrial equator, as is shown by a cosmosphere, or a terrestrial globe, surrounded by a transparent celestial globe, as described in a particular treatise on Cosmospheres.

II. Every large circle through the poles of the world, and perpendicular on the equator, is likewise a *celestial meridian;* and is called a circle of *declination.*

III. Similarly as latitude and longitude are counted on a meridian and on the equator of the earth, so the *declination* and *right ascension* are shown by the circles of declination and right ascension, for a celestial body, to point out its situation in the sky.

IV. The *ecliptic* is a large circle, inclined about 23.5 degrees on the equator; it represents in the sky the orbit in which the earth moves round the sun, or in which the sun appears to move round the earth, as both are always seen from each other in a diametrically opposite direction in the sky, and exactly as two bodies, one moving round the other in a circular room, would appear to the other, or, *vice versa,* if its place were seen as if on the walls of the room.

V. The poles of the ecliptic lie 90 degrees, and at an equal distance from it; it is divided into 12 equal parts, called signs, each of which contains, consequently, $\frac{360^\circ}{12}$, or 30 degrees.

VI. The *celestial longitude* and *latitude* are the same in the sky, in regard to the ecliptic, as the terrestrial latitude and longitude is to the equator on the earth.

VII. The circle of the ecliptic intersects the plane of the equator in two points, which are called the *equinoctial points;* the one, where the ecliptic approaches the north pole, the *equinox of the spring,* and the other the *equinox of autumn.* The two places where the ecliptic is farthest from the equator, are called the *solstitials;* the one in the northern hemisphere the *solstitial of summer,* the other the *solstitial of winter.* Through them, equally distant from the circle of right ascension, lie the *tropics;* and through the equinoctial and solstitial points, and the poles of the world, lie two large circles, called the *colures,* and named likewise according to the seasons, and similarly as the equinoctial and solstitial points. The right ascension is counted from the solstitials of spring, from the west to the east.

VIII. Each sign in the ecliptic has its name: these names were given to configurations of certain stars about 2200 years ago. The place to which the axis of the earth pointed at that time, has however changed, as both the poles of the world turn about every 25,900 years, or during the great Platonic year, in two circles, called the circles of precession, at a distance of about 23.5 degrees, round the corresponding poles of the ecliptic. From this it results, that the signs of the constellations along the ecliptic, as they change their position proportionately as the poles, have another position, in regard to the place where the axis of the earth pointed to at that time. As, however, the poles of the world have changed in position, so will the circle of right ascension have changed its situation accordingly. It has moved in the same direction as the pole of the world, and changed its place round from east to west; and the same is the case with the equinoctial points; consequently the longitude of the constellations will be greater; and we find that the signs of the ecliptic have advanced (as $\frac{26,000}{2,200}$ give nearly 12) about one sign. But, in astronomical calculations, the beginning of the places of the names of the constellations is counted on the ecliptic the same as before, viz.—

				Equal Signs.	Equal Degrees.
The Ram	or	Aries	♈	0	0°
The Bull		Taurus	♉	I.	30°
The Twins		Gemmini	♊	II.	60°
The Crab		Cancer	♋	III.	90°
The Lion		Leo	♌	IV.	120°
The Virgin		Virgo	♍	V.	150°
The Scales		Libra	♎	VI.	180°
The Scorpion		Scorpio	♏	VII.	210°
The Goat		Capricornus	♑	VIII.	240°
The Archer		Sagittarius	♐	IX.	270°
The Water-pourer		Aquarius	♒	X.	300°
The Fishes		Pisces	♓	XI.	330°

IX. The changing of the place of the equinox is called the *precession of the equinoxes,* although the equinoxes recede on the ecliptic; but by this the celestial longitude of the stars is increased.

X. To show the precession of the pole more distinctly, an *Orbograph,* or ring with divisions on it, and to which a semi-ring has been fixed, is to be applied. In fixing it by a pin in the pole of the ecliptic, over the same point of the globe, and turning it round this pole, the pole of the Orbograph, or the pole of the world, will show the precession of the pole and equinoxes; and it is clearly explained by turning the pole of the world from east to west. The 259th part of a circle shows nearly the percession of the pole in 100 years.

XI. The sun being always seen from the earth, while the latter moves in its orbit round the former in a diametrically opposite direction, or sign of the sky, has given rise to the saying, the sun's *apparent motion,* and the sun is in the first or second sign, or the ram, or the bull, or the twins, or in such a longitude.

Sec. 4.—I. Both the terrestrial and celestial globe may have a dial-plate answering to the division on the equator, and which turns either with the axis, or on which a hand turns, with the axis of either globe, to show the hour. This becomes, however, superfluous; and it appears preferable to show the hour by a semi-circle moving round both poles, or a moveable meridian, which, with the strong brass circle, representing the principal or general meridian, will show any horary angle or difference of longitude on the terrestrial, and the difference of right ascension on the celestial globe. Such a semi-circle is called an *hour circle.*

II. The quadrants of altitude are, for both globes, to be represented by two properly divided quadrants, moving with an open centre round a tube, to be fixed by a hook and a screw of pressure, to any part of the meridian of either of the globes. In the centre of the tube, called the *tube of the axis of altitude*, is a pin, which is fixed so as to show any latitude on the division on one side of the strong meridian; while the quadrants of altitude may be moved round the centre of the tube, and consequently be applied to point out any altitude; and if the horizon be adjusted to it, likewise any azimuth or amplitude, and *vice versa.*

III. To point out any altitude more distinctly, bars sliding along these quadrants have been introduced. A notch and a pin on these bars show any ray of altitude seen from the centre of the world, or from the earth supposed to be in this centre, as astronomers always do in regard to fixed stars; but which is to be reduced to the centre of the earth in respect to the sun, the moon, and the planets.

To the tube of the axis of altitudes, and the bars of altitude, micrometer screws and magnifying glasses may be applied, if a higher degree of accuracy be required.

They will not, however, be required for common explanation; and besides, their use being so very simple, they need not be described here.

Sec. 5.—I. For marking the place of the sun or the moon, a certain quantity of glass paper will always be given with each globe: cutting a small piece off, and moistening it a little, it will stick in a temperature of 20 degrees Reaumur, if gently pressed to the surface of the globe. This small piece of glass paper is always to be stuck on the globe so that the required spot may be marked with accuracy, and according to the given right ascension and declination, or according to its longitude or latitude, by two cross lines drawn on it by a fine pin.

II. The places of the sun and moon, and of stars, like the place or track of a vessel at sea, if accuracy be required, is always to be traced on glass paper, stuck to the proper part of the surface of the globe. The stars which have been marked on the celestial globe, can only be used for common purposes, as the pasting of the paper, and the varnish and parallax of them, will never show their correct place. These traced places of the stars on the globe are, however, a guidance in general.

III. The glass paper is particularly useful for large globes in tracing the track of a vessel: and along an unknown coast which is to be traced, or of which views are to be taken, it will afford the greatest facility to effect the proposed task with ease, dispatch, and accuracy.*

Sec. 6.—I. The axis of the earth being perpendicular on the plane of the equator, will incline under a certain direction, or under 90--23.5, or 66.5 degrees on the plane of the ecliptic (Sec. 3). It points meanwhile always to the same part of the sky, or is always inclined under the same angle in the same direction on the ecliptic: the earth will therefore, in revolving round the sun, have her axis inclining, at different times, more or less on the direction between the centre of the earth and the sun, as this line lies always in the ecliptic, or the same plane, but turns round the centre of the sun and earth, while the earth moves round the sun.

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* It will only require a little exercise to get acquainted with the materials. When this is attained, the cross lines, with a fine pin, and proper management, may be drawn as narrow as one five-hundredth part of an inch: and never, in such a case, will greater error be committed, which may be seen by examining the tracing with a magnifying glass.

II. It will therefore, some time or other occur, that, while the earth revolves round the sun, her axis will incline under the smallest angle, or 66.5 degrees on the direction between the centres of the earth and of the sun.

But at other times, or when the earth is exactly in the opposite direction, the angle will be the largest, or equal to 180—66.5, or 113.5 degrees. At an equal distance from both opposite points, the earth's axis will be inclined under 90 degrees, or under a right angle, on the direction between the centres of the earth and sun. And thus will the inclination of the earth's axis on the line between the centres of the earth and the sun, increase from its smallest inclination to the largest, and again decrease from the latter to the former, while the opposite part of the earth's axis forms the supplementary angle of the former, with the direction between the centres of the earth and the sun.

III. Meanwhile, however, the sun will only illuminate one-half of the earth, or all parts, which are not above 90 degrees from the part in the zenith of which he is seen. Consequently the earth will only be illuminated to both the poles when the axis is 90 degrees inclined upon the direction between the centres of both bodies. When this angle, however, gets smaller in one hemisphere of the earth, it always gets larger in the other, as both lie in a straight line round the centre of the earth on its axis, and as their sum is always equal to 180 degrees. The sun will therefore sometime illuminate the pole of one hemisphere, while the pole of the other is not illuminated; and as the earth's axis is sometimes inclined 113.5 degrees on the direction between the centre of both bodies, it will not illuminate any part 113.5,90 or—23.5 from the pole, but will meanwhile illuminate to 23.5 degrees at the other side of the other pole.

IV. Hence it results, as the earth always turns round its axis, that,

First, such parts of the earth as are less than 23.5 degrees from a pole, will sometimes be continually illuminated; while those in the opposite hemisphere have, during the time that the sun is above 90 degrees from their zenith, continual night.

Secondly, such parts as lie more than 23.5 degrees from the pole, may see the sun every day; and,

Thirdly, such as lie less than 23.5 degrees from the equator, will sometimes have the sun in their zenith.

V. The greater or less distance of the sun from the zenith of an observer, causes the seasons. In the hemisphere, where the earth's axis is inclined under the greatest angle, on the direction between the centres of the earth and sun, the winter begins; the sun being in the solstitium of the opposite hemisphere. Meanwhile, however, the angle between the earth's axis in the opposite hemisphere, with the direction between the centres of the earth and sun, will be the smallest, and the summer begin. If, however, the angle between the earth's axis on the direction between the centres of the earth and sun be 90 degrees, the equinoxes will take place: viz. in the hemisphere where the said angle decreases, the autumn, and in the other where the contrary is the case, the spring begins, and day and night are equal all over the earth. These explained appearances will be true for either hemisphere.

VI. Whenever the angle between the earth's axis, and the direction between the centres of the earth and sun increase, then the sun will, at noon on the following day, be higher above the horizon of a place; and, on the contrary, if this angle decrease, the sun will be lower above the horizon every following day, and thus will the changes of the seasons be caused.

VII. All this will best be explained by a terrestrial globe being moved round a light in a large room, always directing its axis to a distant place seen from a window.

Sec. 7.—I. From the apparent changing of the sun's place between the tropics, originates the dividing of the earth into rings, parallel to the equator, or into zones, (Sec. 2. VI.)

II. The sun will be twice every year in the zenith of every part of the tropical zones; while those in the polar zone, whose zenith is above 90 degrees from the sun, will not see him: consequently in the opposite hemisphere, where the sun is, will be continual night; and those in the opposite polar zone, whose zenith is less than 90 degrees from the sun, will have continual day. The inhabitants of the temperate zones will see the sun every day, but their zenith will have the greatest distance from the sun, and the longest night, if the sun is in the solstitium in the opposite hemisphere; but if the contrary, they will have the longest day, and the sun will be nearest to their zenith.

III. Considering the shade of an object, it will, in the tropical zones, sometimes have no shade, and in the temperate zones, only the shade towards one side; but in the polar zones, will have the shade sometimes all round its place in one day.

Sec. 8.—I. The celestial globe is properly, as is generally known, an inverted representation of the sky. If the surface were transparent, and the observer placed in the middle of the globe, the representation would be more perfect. In viewing, therefore, a celestial globe, the observer ought to suppose he occupies a place on the outside of a sky. Suppose, therefore, a terrestrial globe, in a transparent celestial, like a Cosmosphere, a representation of the universe would of course be more perfect.

II. An observer can only see one-half of the stars on the sky at the same time, as the stars under the horizon are always invisible. The same will be observed, if a terrestrial globe, with an horizon round it, be placed in a transparent ball; it will show, that only one-half of the transparent ball is at the time over, while the other half is under the horizon, as the horizon is a plane which lies through the centre of the earth, while this is considered to be in the centre of the sky.

III. In observing the sky, we perceive the stars slowly moving from the east to the west. This apparent motion is, however, produced by the earth turning once every day round its axis. It will be clearly explained by turning the terrestrial globe, with the axis pointing to two opposite points of a room, if the room be considered as a representation of the sky.

IV. The horizon corresponding to a point on a terrestrial globe lies round it; and in a similar way it may likewise be supposed to extend beyond the sky; and therefore an horizon may be laid round a celestial globe, particularly as the observer is supposed to be outside of it, without representing any part incorrectly. Such an horizon being an extended plane of the true horizon, will therefore show the rising and setting of celestial bodies, as well as a Cosmosphere.—(See the Treatise on a Cosmosphere.)

V. It will be seen, as is really the case with the stars in the sky, in turning the celestial globe from the east to the west, and putting the earth's axis in the horizon, that all stars will appear to move round the axis of the world; some will rise perpendicularly, others inclined; they will all attain a greater, the greatest, and less height, and set again: those near the pole hardly change their position, and all describe an arc in the sky. An arc described by a star above the horizon, is *his diurnal arc.* Putting the globe so that the pole is at an equal distance from the horizon, and turning it, only one-half of the stars on the globe will be seen above the horizon to revolve round its axis, while those near the zenith describe the smallest, and those near the horizon the largest circles. Putting, however, the pole between both-mentioned positions, some stars will rise, get a greater, the greatest, a less, and the least height. These describe small circles above the horizon round the pole ; but the nearer the stars are to the pole, the smaller will these circles be; while other stars rise, culminate, and set.

VI. The stars which can be seen from any place, are shown by fixing the tube of the axis of altitudes, with its centre on the meridian of a celestial globe in the latitude of the observer. All those stars which, in turning the globe, come under the end of a quadrant of altitude, or above the horizon, can be seen some time or other. A circle drawn through that part of the sky, which some time or other can be seen, is called the *circle of permanent occultation.* Other stars will always remain over the horizon; and a circle drawn on the globe through the points which never go below the horizon, is called the circle of *permanent apparition.* And thus it results, that every observer, who is not under the equator, has a circle of permanent apparition, and one of permanent occultation; but any one under the pole, only the latter. Such as live not under the equator, or in a pole, see, sometime or other, all the stars of their hemisphere of equal name, and such stars of the other hemisphere whose declination is equal to the difference of 90 degrees less the latitude of the place.

VII. Whenever a celestial body attains its greatest height above the horizon, it will be in the meridian; for the northern hemisphere, it will be in the south ; and for the southern hemisphere, in the north · when this happens, it is said to *culminate;* and regarding the moon, this is sometimes called *southing*.

VIII. The time during which the earth turns round her axis, so that the same stars come again in the same position as they were the day before, is called a *sideral day*.

IX. The sun appears continually to change his place in the ecliptic, while the earth moves round him, as mentioned in Sec. 6.; but the earth moving round the sun in the same direction as she turns round her axis, will make the sun visible, every following day more advanced in the ecliptic, or in the sky, than the day before; therefore the earth must, to render the sun visible in the same direction as the day before, turn a little more, as in regard to a fixed star; or the earth must turn once completely round her axis; and as much more as the sun has meanwhile advanced in the sky, to bring the sun again in the same direction. The time which the earth takes to turn round her axis, to have the sun over the same place as the day before, is called *a solar day,* and it is longer than a sideral day.

X. The sun's apparent motion in the ecliptic is, however, not regular; it advances sometimes about 57, sometimes 61 minutes, during 24 hours, or daily about 59.5 minutes. This makes, taking the sun's apparent mean motion on the equator, only 59 minutes 8 seconds to complete a mean solar day.

XI. The sun's irregular apparent motion in the ecliptic, while the earth turns regularly round her axis, will cause one day to be longer than another, to bring the sun again in the same position as the day before. Therefore will the solar day, or the time from one noon to the next, not always be of the same length; and the length of a solar day be different from a mean day. This difference is called the *equation of time;* and the time which is always uniform, or the days which are considered to be of equal length, is the *equated* or *common time*, and it is applied in common life. The difference of it from solar, or apparent time, for every day, is found in astronomical tables.

XII. The reason why the sun does not appear to advance every day an equal space, is, because the orbit of the earth round him is not circular, but oval, or an ellipse; while the sun is not in the centre, but in one of the foci of the orbit. Whenever the earth is nearest the sun, it is in its *perihelion*, and if farthest from it, in its *aphelion*.

XIII. The mean space which the earth daily advances, or 59 minutes and 8 seconds, makes only one-fifteenth of it or 3 minutes 56 seconds in time; therefore a solar day is only 23 hours, 56 minutes, and 4 seconds of mean solar time.

XIV. The dial-plate, and the hand, as well as the hour marked on the globe and the hour circle, always show sideral time, as it is adjusted to 360 degrees of the celestial globe: if the globe be turned from the east to the west, it will show under the meridian a later, but if turned the other way, it will show an earlier hour.

XV. As the stars are only visible after the sun is several degrees under the horizon, and as the sun advances daily in the ecliptic, different stars will every day after sun-set always be seen to rise and to set. Stars which were not seen the evening before, will rise after sun-set in the east, but others will at the same time set sooner or earlier in the west. This is clearly shown by a celestial globe, marking the sun's place for several following days, and bringing it in the horizon: there will appear every evening new stars more to the east above the horizon, while others in the west will set sooner at the same time.

Sec. 9.—I. The apparent place of the sun is found in tables, and on the improved calendar for the same place in the ecliptic; but for a mean year, between three common and a leap year, on the stand or calendar for this purpose, and by marking the same point of the ecliptic, or the right ascension and declination of the corresponding point on the celestial globe (Sec. 5), the sun's place in the sky is shown. To bring such a part of the ecliptic on the celestial globe, showing the sun's place for a certain day, under the divided side of the meridian, is termed, *to set the sky.*

II. The tables, as well as the calendar for the sun's place, and an analemma, correspond for the same longitude on our earth. But if the sun's place for another longitude be required, an allowance is to be made according to the difference of longitude, as the sun will apparently advance about a degree, while the earth turns round her axis, so as to complete a solar day. This allowance is to the difference of longitude as the sun's apparent motion in 24 hours is to 360 degrees, and according to the difference of longitude; if to the west it is subtractive, and if to the east, additive from the sun's place for noon in the ecliptic, as given in the tables.

III. If the sky is set, the clock must likewise be properly pointed, and of course mark 12. To bring the clock or the hour circle under the meridian, to mark 12, is termed, *to set the clock.*

IV. Observations taken from a certain latitude, require the horizon to correspond with the declination of the zenith. To fix the horizon corresponding to a certain latitude, is termed, *to set the horizon.*

V. The tube of the axis of altitudes, with the quadrants of altitude, should be placed on the meridian, so that the observed altitudes may be shown according to a certain latitude, or part of the sky. To bring the tube of the axis of altitudes with its centre over that of the sun or moon, or over a star, or in the zenith, is termed, *to set the tube of the axis of altitudes over the sun, or moon, or star, or in the zenith.*

Remark. Any one wishing to solve problems, or to make use of cosmospherically mounted globes, must perfectly understand how to set the sky, how to set the clock, how to set the horizon, and how to bring the tube of the axis of altitudes over a certain point; when he will be able, after getting acquainted with the motions of the globe, and its parts, to solve any problem with ease, dispatch, and accuracy.

Sec. 10. To find the difference of the hour of one place from another, is done by bringing the first place under the meridian, observing the clock or degrees of right ascension, and turning either of the globes till the other place comes under the meridian. If the terrestrial globe be turned from west to east, to bring the second place under the meridian, its time will be after; but if turned from east to west, the time of the second place will be before that of the first.

Sec. 11.—I. To know a certain star seen in the sky at a certain time, is done by setting the horizon, the sky, and the clock on the celestial globe, and turning the globe until the given hour be under the meridian: the celestial globe will then show the inverted position of the sky; and if turned according to the corresponding point of the compass, any star will easily be found at the given time.

II. In a similar manner may any number of stars be found, and their names be known; but if more accuracy be required, the quadrants of altitude will give the star's altitude, and its azimuth after setting the horizon; if the tube of the axis of altitude be brought over the zenith of the observer, and a quadrant of altitude applied, to find the altitude and the azimuth of the star on the instrument, and *vice versa,* if the altitude of a star has been observed.

III. As mentioned in Sec. 1, the hour may likewise be found when a star will set or rise, or culminate, by setting the horizon, the clock, and the sky, and turning the globe until the given star set, rise, or culminate: then the difference of the hour, or of the degrees of right ascension from noon, shown by the clock or hour circle, will show the required hour.

IV. In turning the celestial globe, after setting the horizon, the sky, and the clock, it will likewise show, first, that from places of the same latitude the same stars will be seen, but at different times, according to the longitude; and, 2ndly, that from places of the same longitude the same stars will culminate at the same time.

Sec. 12.—I. To find for a given place at a given time, the sun's altitude and azimuth, is done by setting the horizon (Sec. 9), and bringing the tube of the axis of altitude on the meridian of either of the globes, over the declination of the sun, for the corresponding day and longitude (Sec. 9), and turning the globe, so as to mark the given hour from noon; then will the altitude and azimuth of the sun be shown by a quadrant of altitude on its division and on the horizon, if perpendicularly on it.

II. Thus, from the sun's place, or from a given altitude, and the hour from noon, or the horary angle, or the altitude for a given day, (Sec. 9. IX.) may the latitude of a place in the inverted manner be found.

III. The diurnal arc of the sun, or the length of a day, may thus likewise be found; but as the upper brim of the sun appears to an observer when it is about half a degree under the horizon (as will be explained afterwards), an allowance is to be made for this, as well as for the apparent motion of the sun during the time, from noon to his setting or rising.

Sec. 13.—I. While the sun moves apparently forward in the ecliptic, the moon revolves in her orbit (which inclines about 5.4 degrees to the plane of the ecliptic), but a great deal faster than the earth, or about 13 degrees in 24 hours, and in the same direction from west to east.

II. The moon describes, in regard to the same fixed stars, her sideral revolution, or her orbit round the earth, in 27 days, 7 hours, 43 minutes, 12 seconds; but as the fixed stars attain, during this time, another position, on account of the precession, this causes an alteration in th time in regard to the precession of the pole, and change the real time in which the moon moves round the earth into 27 days, 7 hours, 43 minutes, and 5 seconds, which i called the moon's *periodical revolution.*

III. During the time which the moon makes her sidera revolution, the earth has moved 29 degrees, 6 minutes and 28 seconds, in her orbit. The moon passes this spac in 2 days, 5 hours, 1 minute; therefore her revolutio round the earth, in regard to the sun, will require so muc time, or 29 days, 12 hours, 44 minutes, and 12 seconds which is called her *synodical revolution.*

IV. The motion of the moon being before, or swifte than that of the earth, will cause the former, after bein near, or in the same direction as the sun the following day to move to the east of the sun, and consequently to ris and set later than the sun every following day.

V. The moon's orbit intersects the ecliptic in two points called her *nodes:* the one after which she moves to th north is called the *ascending node,* and it is marked thus ☊ the other, the *descending node,* and is marked thus ☋; th line between both is the *line of nodes.* This line of nodes and the places of the moon's nodes, change their position they move backwards from east to west in the zodiac (part of the sky 10 degrees at each side from the ecliptic) but they come every 19 years again in the same position.

VI. A ball can only be illuminated on one side or one half of it at the same time by a light; and on the sam principle the sun can only illuminate one-half of a larg ball, like our earth or the moon, both being at a great distance from it.

VII. The moon being, like all balls, only at the sam time one-half illuminated by the sun, will, however, no appear so, to any one who sees the side which is turne from the sun, and will show her illuminated side only i seen in the same direction as the sun; consequently if the sun is opposite the moon, or six signs from her, then her illuminated side will be seen from the earth; this is called a *full moon;* but if the sun and the moon are in the same signs, her illuminated side is turned from the earth, and will not, consequently, be seen from here: this is called the *new moon.*

VIII. The diurnal arcs of the moon are likewise the largest when the distance of her centre, or when in that part of her orbit which has the smallest distance from the zenith, and when her declination in the same hemisphere is the largest; but the moon's orbit only deviating a few degrees from the apparent orbit of the sun, will cause her to describe, when seen near the sun, or in the same sign of the ecliptic with the sun, nearly the same diurnal arcs as the apparent diurnal arcs of the sun; but if diametrically opposite to the sun, or in the opposite sign, to describe nearly the same diurnal arcs which the sun apparently describes six months before or after the time: consequently the diurnal arcs of full moon will be the largest when the sun is in the opposite hemisphere, or in the hemisphere which has winter, and be the largest for the time of the new moon, or for the hemisphere which has summer.

IX. The sun's apparent diurnal arcs are larger, if in the same hemisphere, for places nearer the pole, than for a place, the latitude of which deviates less from his declination. It will be seen from this, and from V. and VI. that the moon describes the largest diurnal arcs for places nearer the pole, in the time of the full moon during the winter, and the smallest during the new moon, or in summer.

X. The diurnal arcs which the moon describes round the earth will, in proportion as they increase from a full or a new moon (which places in her orbit are likewise called the *syzigies* of the moon), cause different appearances of the illuminated part (or of the phase) of the moon; and if, therefore, at 90 degrees from a full or a new moon, only one-half of her illuminated side will be seen.

XI. The moon revolving from west to east round the earth, will, at 90 degrees from a new moon, show the illuminated side to the right hand: this is called the *first quarter;* but after full moon, it will show, at 90 degrees from this place, the illuminated side on the left side, or the moon's *last quarter,* as the motion of the moon is faster than the apparent motion of the sun. Whenever the moon is in her first and last quarter, she is said to be in her *quadratures.*

Sec. 14.—I. Eclipses are phenomena which originate from an opaque body coming between two others, one of which illuminates the other: that part of the last-mentioned body which is deprived of light from the first by the opaque body between them, is said to be eclipsed. This word is, however, in general applied only to the moon and the sun. The earth, as well as the moon, throw, as they are smaller than the sun, a conical shade, the base of which is a large circle through their centre, and the height of which depends upon the distance of either from the sun.

II. If therefore the moon comes between the sun and the earth, so that her shade renders part of the earth invisible to the sun, then the sun, or rather the earth, will be eclipsed by the moon; and if the earth comes between the moon and the sun, then the moon will be eclipsed by the earth. The former is called an eclipse of the sun, and the latter an eclipse of the moon.

III. If the moon is entirely before the sun, it is a total *eclipse of the sun:* should, however, only a part of her shade, or half her shade, meet the earth, then it is a *partial eclipse;* and when the shade of the moon does not meet the earth at all, but is seen before the moon, it is a *ring-shaped eclipse.* This will, however, only be seen from a few parts of the earth.

IV. The shade of the moon being much smaller than that of the earth, is the cause of solar eclipses not happening so often as lunar eclipses. It may likewise occur, while an eclipse takes place, that the shade of the moon will eclipse only some parts of the earth: care must therefore be taken in forming common calendars, (which generally copy parts of an astronomical ephemeris,) that the time of the place, whether the moon is visible, and how far an eclipse extends, be properly mentioned, as the astronomical ephemeris has been calculated for a certain place only. Sec. 10.

V. Eclipses may be found by a celestial globe, by tracing the moon's place given in an ephemeris, when in its nodes; if it is in the same place with the sun, an eclipse of the sun will take place; but if diametrically opposite to the sun's place, an eclipse of the moon will take place.

VI. The shade of the earth meeting the moon's brim at one moment, furnishes means for calculating the longitude of places, if the exact hour of such time has been observed; as the difference of the hour, multiplied by 15, will show the minutes and degrees of longitude. (Sec. 10.) The time of lunar eclipses ought therefore always, and, if possible, the moon's altitude at the same time, to be observed.

Sec. 15.—If the moon or a planet is diametrically opposite to the earth, or 180 degrees from it, or if two planets are thus situated, they are said to be in *opposition*, marked thus ☍; but if planets are (if seen from the sun) in the same direction, they are said to be in *conjunction*, and are marked thus ☌. If one planet is at an equal distance, or 90 degrees from the situation of another, it is said to be in the *quadratures*.

II. The place of a celestial body, as seen from the sun, is termed its *heliocentrical* place; but, as seen from the earth, it is called their *geocentrical* place.

Sec. 16.—In the same direction in which the moon's nodes move backward in the ecliptic from east to west, so has the earth likewise a motion, caused by the attraction of the moon and sun. The earth moves on this account, or recedes in the ecliptic, 50′ 2″ every year, and so much will the pole of the equator recede, which is called *the precession of the pole.* While this takes place, the equator, and all appertaining lines, have a motion conformably to that of the poles, or the equator recedes on the ecliptic, by which, of course, the celestial bodies will have annually a greater longitude, and a change in declination and right ascension: their latitude or distance from the ecliptic, however, remains always the same.

Sec. 17.—The earth having a larger diameter between two opposite points in the equator than between her poles, has a greater thickness near the equator. This redundant matter is attracted by the moon and sun; and from this arises another irregularity in her orbit, viz. the earth's axis describes a small ring in the sky, round the pole. This deviation of the earth's axis is called its *nutation*, and after every tenth year it is again the same as before, but causes a change in the places of the stars of about 18 seconds, and is therefore only applied where great accuracy is required.

Sec. 18.—It is generally known, and may be observed by holding a stick in a bason of water, that a ray falling into a denser matter, is deflected from its straight direction, and in the same way is every ray from a celestial body bent or deflected, if it come in the atmosphere which surrounds our earth, or in the air, which always gets thinner at a greater distance from it. This deflection of a ray of light is called *refraction;* and it being always in the direction of the centre of the earth, it causes celestial bodies to be seen before they really are in the horizon, and in the same way it will always cause them to be seen higher or above the horizon, as they really are; and from this it results, that refraction is subtractive from any measured altitude.

Sec. 19.—Another correction to be applied to the celestial bodies, is caused by the comparative velocity of our earth, and the swiftness of light. It will require a short interval of time for a ray of light to pass through a telescope, while the earth moves regularly; therefore, in observing a star, the telescope is to be pointed so that its axis may deviate a little from the direction of the star, like a gun pointed to a flying bird. The correction arising from this, respecting the places of stars, is very small, as a ray of light passes in eight minutes and seven seconds from the sun to the earth, and as light is 10.313 times swifter than the motion of the earth. This makes the angle under which a telescope is to be pointed very small, it is only at most 22 seconds. This angle is called the *aberration* of a star.

Sec. 20.—An angle, of which the vertex lies in the centre of a celestial body, and which, if the object is in the horizon, is formed by two lines from thence, one to the centre of the earth, and the other as a tangent to its surface, and which angle is consequently subtended by the semi-diameter of the earth, is called the *parallax* of a celestial body. It is largest when the celestial body is in the horizon as described, but smaller when the celestial body attains a greater height; and it vanishes when the celestial body is in the zenith, as the said angle is largest when the line which subtends it is perpendicular upon either of the lines which form it, and gets smaller the greater the angle becomes, under which the subtended line (which is always equal to a semi-diameter of the earth) is inclined to either of the lines forming the angle. All celestial bodies, whose distance can be measured, have a parallax, and the nighest have the largest. This parallax prevents, however, a celestial body being seen so soon as it otherwise would, or gives a less height than the celestial body really has; it is therefore additive to the measured altitude.

Sec. 21.—An observer being above a plane which forms his visible horizon, will not see the objects in the horizon as in the natural horizon: there is, therefore, a certain correction of an observed altitude to be made for the height of the observer's eye above the surface of the sea. This deviation of the visible horizon from the real horizon is called its *dip*. As an object in the horizon can sooner be seen by it than in the true horizon, a certain quantity is therefore to be deducted for it, from every observed altitude.

Remark.—In mentioning the sun, or the moon, or a planet, it is understood, as a matter of course, that its centre is always meant. Tables for correcting the altitude of an observed object, in regard to refraction, to the dip of the horizon, to the parallax, to aberration, to nutation, and to precession, are found in astronomical works, and in catalogues, showing the places of stars, and for every year, and in an ephemeris.

III.—On the Solving of Problems by Cosmospherically mounted Globes.

Sec. 22.—To find the right ascension of the zenith of a given place at a certain hour. (Celestial globe.)

I. Set the sky, and set the clock, or bring the hour circle under the meridian.

II. Turn the globe as much as the given hour, reduced to degrees, minutes, &c. requires; then the right ascension of the zenith for the given time will be found under the divided side of the meridian on the circle of right ascension.

Remark.—The right ascension of the zenith of a place is generally found by adding or subtracting the right ascension of the sun's place at noon, to or from the horary angle, reduced to an arc.

An hour-circle will contribute to find it better, and to a greater advantage, by proceeding as mentioned in I., then the right ascension of the zenith will be found under the meridian on the equator, by turning the globe as much as the given hour requires; should it be requisite to mark the zenith, it is to be done by glass paper, as mentioned in Sec. 5.

Sec. 23. To find the diurnal arc of the sun for a given day. (Celestial and terrestrial globe.)

I. Set the horizon, mark the sun's declination on the meridian, and the longitude or right ascension then under the divided side of the meridian, or the hour.

II. Turn the globe until the horizon meets the sun's place on the divided side of the meridian, and mark the right ascension, or the hour now under the meridian. The difference of right ascension or the hour first and last marked, divided by 15, will give the horary angle for half the diurnal arc.

III. The circle of the hour will, if the place of declination be marked on it, describe the diurnal circle of the sun.

IV. In the same manner may the diurnal arc of any celestial body be found: if, however, the moon's diurnal arc be required, a proper allowance is to be made for her motion from noon, to the time when she sets, or rises. The same is likewise to be done respecting the sun or planets, if great accuracy be required.

Sec. 24. It is required to know a certain star seen above the horizon at a certain hour. (Celestial globe.)

I. Set the horizon, the clock, and the sky, and turn the globe according to the given hour, or the angle of the hour.

II. Put the globe in such a position that the meridian of the globe may be in the corresponding line on our earth, from the south to the north. Then the position of the starred sky will be represented by it, and the star comparatively to others be found.

III. But if the altitude of a star has been measured, then mark this on a quadrant of altitude, and the star will be shown by the marked altitude, and horary angle or azimuth, after the tube of the axis of altitudes has been fixed on the meridian over the zenith of the observer, and the quadrant of altitude been turned according to the horary angle or azimuth.

IV. In a similar manner will the place of a planet be found, if its place for the day has been marked on the sky.

Sec. 25.. To find the time of culminating, setting, or rising of a certain star. (Celestial globe.)

I. Set the horizon, the clock, and the sky, and mark the degrees of right ascension.

II. Turn the globe until the star set, rise, or culminate, and mark the hour or the degrees of right ascension. Then will the required time from noon be shown by the difference of right ascension, or by the hand on the dial-plate.

III. The time when a star will have a certain amplitude, or altitude, will, in a similar manner, be found by the quadrant of altitude, after the tube of the axis of altitudes has been set over the zenith of a place.

IV. In the same way will likewise be found the time of the culminating, rising, or setting of the moon, or whenever she will have a certain altitude or azimuth, making allowance for the changing of her place during the time from noon, according to the tables.

APPENDIX.

ON

THE USE OF COSMOSPHERICALLY MOUNTED GLOBES, OF AN ORBOGRAPH, OF A LOXODROMOGRAPH, AND OF A SPHEROMETER,

FOR CALCULATING

LATITUDE AND LONGITUDE AT SEA.

Sec. 26.—I. THE use of instruments generally employed for ascertaining the place of a vessel at sea, will not be mentioned here; but, as the most expert calculator is subject to commit a fault in calculation, it is desirable to have an instrument which represents every part, and which may serve as an argument in his calculation, similar to nature.

II. Cosmospherically mounted globes show every part of the surface of our terrestrial globe, and every arc in the sky, as if measured from the centre of our earth: they will serve to solve all problems of plane sailing, of parallel sailing, of middle-latitude sailing, of oblique sailing, of globular sailing, and also the time of tides at given places: the setting and velocity of currents, the effect of trade winds, &c. may be better explained, and their influence, whether additive or subtractive, clearly shown, and illustrated by cosmospherically mounted globes; and such globes, or a cosmosphere, appear therefore to be a requisite instrument, in this respect, for every navigator.

Sec. 27.—I. The accuracy to be obtained from cosmospherically mounted globes, depends upon the correctness of their make, and the length of their diameter. Before they are made use of, they ought to be examined by sufficiently intelligent persons, or a competent individual, who feels the greatest satisfaction in promoting useful knowledge, and assisting the navigator, whenever, by storms or other circumstances, he is out of calculation; or when he is to depend upon astronomical observations, as measured altitudes, distances of celestial bodies, or observing two of the latter in a plumb-line, as will be shown in the following pages.

II. The accuracy of cosmospherically mounted globes depends, secondly, upon the diameter of the globe. It may be supposed that an unarmed eye can see one-hundredth part of an inch, and in this case it will distinguish

	5	minutes on a	15	inch globe, having	47.13	inches in diameter.
	4	——	18	——	56.55	——
nearly	3	——	21	——	65.98	——
fully	3	——	24	——	75.40	——

But, as every given or found latitude or longitude will be twice indicated on the instrument, and as micrometer screws, or verniers, with magnifying glasses, may be applied to cosmospherically mounted globes, an accuracy of nearly as many seconds may be obtained as minutes were mentioned, which is shown by every instrument * to which micrometer screws, verniers, and magnifying glasses are applied. Taking now the twice, or doubly indicated just-mentioned magnitudes, and three times repeated operation, it will result, that an accuracy may be obtained of

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* Any person in the possession of an octant, or sextant, or quadrant, with a good division, to which micrometer screws, verniers, and magnifying glasses are applied, will, if sufficiently acquainted with the use of the instrument, know this without further comment.

5 seconds of an arc with a 15 inch globe.
4 —— 18 ——
3½ —— 20 ——
3 —— 24 ——

which gives 0.3 seconds for a 16 inch globe.
0.27 —— 18 ——
0.2 —— 20 ——
0.2 —— 24 ——

in time; and it will require a good chronometer to show one-sixth of this accuracy. This will be considered the accuracy to be obtained by globes; and thus will a 20-inch globe give about 20 seconds of an arc, or about one thousandth part of an inch, which may always be seen by a magnifying glass.

III. Some doubts might, however, be entertained of the above-mentioned accuracy, and consequently of the great utility of these instruments at sea, particularly by persons who, by more important business, may be prevented from pursuing mathematical calculations;[*] but a spherometer[†] will soon disperse these doubts, as it is an instrument which represents every spherical triangle, so that from such given parts as are given in spherics, any spherical triangle may be represented, and of course the unknown parts be shown and found with accuracy, ease, and dispatch, and without any mathematical calculation.

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[*] But, to satisfy every one, a treatise on this subject, with proper mathematical calculations, has been prepared, and will shortly appear.

[†] A spherometer consists, 1st, of a ring, divided into degrees, minutes, &c.; (2), of a semi-circle, which may be turned round its diameter, lying in the divided plane of the ring, so that the points 0° and 180° of the ring and semi-ring fall in one line; (3) of a ruler, which may move round the centre of the ring: on this is fixed another semi-ring, so as to turn, similar to the one mentioned (in 2), round a line, through its points 0° and 180°, and two diametrically opposite points on the ring (1). (4) Loose, but likewise divided arcs, serve to find any spherical angle. Other spherometers have been formed by several semi-rings, some sliding along others, but all moving round open centres. The division of all the rings of every instrument of this kind are all to lie in the surface of a proportionate ball.

IV. As a spherometer is applicable in verifying the solution given by a cosmosphere, or cosmospherically mounted globes, so it may likewise be applied to verify any calculation in spherics. This instrument will become useful to every individual who has to calculate spherical triangles, if he is anxious to save time, which tedious repetitions of such calculations always require, to be convinced that they are made without an error. To point out smaller parts of the divisions, micrometer screws, verniers, magnifying glasses, and loxodromographs may be applied to it.*

V. With these additions, a spherometer may be applied to represent any part of a spherical triangle, or quadrangle, and serve to attain, by any one acquainted with the use of similar instruments, and after knowing the use of a spherometer, an accuracy of from 15 to 20 seconds of an arc.†

VI. The utility of a spherometer, and a cosmosphere, or cosmospherically mounted globes, will however still appear greater, if it is considered that the great number of tables and rules for calculations at sea have often enveloped the principal object with a technical cloud, which is avoided by skilful calculators, while it remains forbidding to less expert ones.

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* A loxodromograph consists of part of a brass ring, with a bar, to which a point is fixed, showing the centre of the instrument, and a bar moving round the circumference, while it points with one end to the centre of the ring.

† Applying this to the accuracy generally to be obtained at sea, in taking altitudes, a spherometer will prove an instrument highly useful for all such calculations. A treatise on the accuracy to be obtained by a spherometer, and showing how far it is applicable to certain calculations, will explain this more, and will show, by mathematical calculation, how far the fluxions of parts of spherical triangles cause a change in others, comparatively to the accuracy to be obtained by a spherometer. See the author's work on Analytical Trigonometry, and on the Fluxions of Plain and Spherical Triangles. Gottingen, 1806, in the German language.

Sec. 28. To trace a loxodromic line, from a given point on a globe, or on a properly constructed map.

I. Set the small moveable bar of the loxodromograph to the point of the compass under which the line is to be traced.

II. Apply the loxodromograph accordingly, putting it with the two hooks over the undivided ring, (fixed to the horizon), so that the diameter between the points 0° and 180°, will lie in the meridian, and the centre of the instrument over the given point of the globe or map it may be applied to.

III. Trace a short line, having the length of a degree or less, along a ruler, from the centre of the instrument to the given point; and continue this line, from the last drawn part, by putting the centre of the loxodromograph, according to the above directions, as from the given point, until the required length be attained.

Remark.—All problems in navigation, where distances are to be traced under certain directions, may be solved by the explained method of drawing a loxodromic line.

Sec. 29. Every observed altitude of a celestial body is, at sea, to be corrected by the dip of the horizon, and the refraction; but the places of the sun and moon, and the planets, in regard to parallax; while the place of fixed stars is to be corrected, a certain quantity, according to precession, nutation, and aberration, as has been explained in many able works treating on this subject. Precession, nutation, and aberration, are generally known for any required time from catalogues of fixed stars, and therefore the great utility of such correct catalogues, with proper tables of correction for a known time, will require no comment.

Sec. 30. To find the latitude by a meridian altitude. (Celestial or terrestrial globe.)

I. Fix the bar of altitude according to the observed and corrected altitude (Sec. 29.), to the corresponding degree of altitude on the quadrant of altitude. (Sec. 9.)

II. Bring the ray of altitude over the declination of the celestial body, as shown on the meridian, after finding it in astronomical tables, or on a correctly constructed globe, or for the sun by an analemma, or by a calendar of the sun's place in the ecliptic, and corrected according to longitude. (Sec. 9.) Then the point in the centre of the tube will show the required latitude on the division of the meridian.

Sec. 31. To find the horary angle from an observed altitude of the sun, if the latitude is known.

I. Correct the altitude found (Sec. 29.), mark it by a bar of the ray of altitude on a quadrant, and set the tube of the axis of the altitudes over the given latitude on the meridian.

II. Mark the proper place of the sun, according to the supposed longitude, and the supposed hour, which gives the declination tolerably true, on the transparent globe, (Sec. 5,) and bring the bar of altitude exactly over it. Then will the horary angle be shown by the distance on the equator between the divided side of the meridian, and an hour-circle, if properly brought under the ray of altitude, or over the sun's place.

III. The horary angle may be before or after noon.

Sec. 32.—I. The horary angle may likewise be found from the observed altitude of a star, or the moon; but the latter moving very fast, is seldom applied for this purpose.

II. The azimuth and amplitude of the sun, or the moon, or of a star, are, after setting the horizon, shown by the point 0° of the quadrants of altitude, if set over the place of the observer, and the divided side of the quadrant over the observed celestial body.

Sec. 33. To find the latitude, and the horary angle, from two observed altitudes of the sun, and the elapsed time between both observations.

I. Mark the sun's declination as found in an ephemeris, and according to the supposed hour, and supposed longitude, for the first; and making good for the passed interval of time, as observed by a well-adjusted watch, likewise for the second observation. (Secs. 5, 9, and 10.)

II. Set the rays of altitude over the observed and corrected (Sec. 29.) altitudes on the quadrants of altitude.

III. Slide the tube of the axis of altitudes along the meridian, and turn the globe until the two given rays of altitude lie exactly over the two marked places of the sun, which, if micrometer screws are applied to the motion of the tube, may be done with great accuracy.

Then the point in the tube of the axis of altitudes will show on the division along the meridian the latitude.

The meridian lying then in noon, the horary angle, or the time of both observations before and after noon, will be found on the equator between the divided side of the meridian, and the circle of the hour if adjusted, so as to pass through the point marking either of the places of the sun.

IV. The azimuth and amplitude will likewise be found after setting the horizon; they will be marked on it by the quadrants of altitude. (Sec. 32.)

Sec. 34.—I. These problems are proved to be true, as well as the following, by considering that observed parts are proportionately represented. The unknown parts in these problems may likewise be found by a spherometer.

II. The solution of the problem (Sec. 33.) is however only true when the observations are made from one place. Should, therefore, a vessel have changed its position during

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the time elapsed between both observations, then of course the change in longitude and latitude, whether towards or from the first horizon, is to be allowed for, to reduce the observations to one point, and to find the facit, as observed in Sec. 33.

Sec. 35.—I. The horary angle and the latitude may be found, in a similar manner, from two observed altitudes of the moon, or a star, and the time elapsed between both observations, if proper corrections be applied (Secs. 29 and 32.) the places correctly traced, and the proper altitudes marked.

II. From this it results, however, that an observed altitude of the sun, or of the moon, or of a star, and another observed altitude of either, or of the sun, or of the moon; or of a star, at the same time, or after a known elapsed time, may be applied to solve the problem in Sec. 33. As, however, the moon's motion is very rapid, and as greater faults may be committed in marking her place by a supposed longitude and hour, than with a star, great care is to be taken in measuring and correcting her altitudes, and in tracing her place.

Sec. 36. To find the horary angle, the altitude and the azimuth, by having observed, in a known latitude, two stars in a plumb-line.

I. Set the tube of the axis of altitudes over the known latitude, and mark the place of both stars on the globe. (See. 5)

II. Turn the globe until both stars are exactly under the divided side of a quadrant of altitude; their centre will then show their altitude on the quadrant of altitudes; the circle of the hour will show on the equator the horary angle, or number of degrees, minutes, &c. comprised between the divided side of the meridian and the hour-circle; and on the horizon, if properly set, the azimuth will be marked by the point 0° of the quadrant of altitude.

Sec. 37. To find the latitude, if the hour is known, when two stars have been observed in a plumb-line.

I. Mark the place of the two stars exactly on the globe, and turn it, so that it may lie in the proper position for the known hour and supposed longitude. (Secs. 5, 9, and 29.)

II. Keeping the globe in this position, set the tube of the axis of altitudes, so that the divided side of a quadrant of altitude may lie exactly over the two given stars. The latitude will then be shown by the centre of the tube of the axis of altitudes on the division of the meridian.

Sec. 38. The observation of two stars being in a plumb-line, can frequently be made; but a good altitude cannot be observed at all times; therefore observations of the hour when celestial objects lie in a plumb-line, ought never to be neglected. Hitherto observations of this kind have very seldom been applied at sea; but their value is well known, and applied by astronomers.

Such observations are, at sea, of the greatest utility, as they serve to find whether a measured and corrected altitude is the true altitude, and thus verify calculations. The calculation necessary to find such a result is sometimes tedious, and is not given here. This subject, as well as the accuracy to be obtained by cosmospherical instruments, will be shown in a particular treatise, to which the reader, sufficiently conversant in mathematics, is referred.

Sec. 39. To find the latitude of a place, the horary angle, the altitude, and azimuth of four stars, two of which have been found by one observer in a plumb-line, while another observer found the other two, at the same moment, in a plumb-line.*

I. Mark the places of the observed stars with all possible accuracy on the globe. (Sec. 5.)

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* This supposition will, however, seldom be the case, unless stars of the fifth, or smaller magnitudes, are observed.

II. Slide the tube of the axis of altitudes along the meridian, and turn the globe until both pair of stars lie exactly under the divided side of the corresponding quadrant of altitude, as observed. Then the centre of the tube of the axis of altitudes will show the latitude on the division of the meridian, and the quadrants of altitude the altitudes. The circle of the hour being put over the centre of a star, will mark on the equator, in degrees, minutes, &c. its distance from the divided side of the meridian. The azimuth is shown by the quadrants of altitude, after the horizon is set, according to the found latitude.

Sec. 40. In case two stars should have been observed in a plumb-line, some time previous to two others being seen in such a direction, the time elapsed having been marked by a good watch, then the horary angle is to be allowed for in tracing the stars on the surface of the globe.

Sec. 41. It has been observed that the difference of degrees, minutes, &c. of longitude, is equal to fifteen times the difference of time in hours, minutes, &c. (Sec. 2, IX.) From this it results, if the time of another place is known, and has been marked when an altitude has, or when two stars have been observed in a plumb-line, that the apparent time for the place of an observer is found by the horary angle, while the hour marked by the chronometer is mean time.

Sec. 42. To find the latitude, the difference of longitude, and the azimuth, from the observed altitudes of two stars, knowing the time of the place from which the longitude is required.

I. Find the right ascension of the zenith of the place from which the difference of longitude is required, according to the known time, and mark it. (Sec. 21.)

II. Mark the correct places of the observed stars on the globe, and the altitudes by the bars of altitude on the corresponding quadrants of altitude, and bring the rays of altitude over the corresponding stars, by sliding the tube of the axis of altitudes along the meridian, and turning the globe, until the proper position be attained: then the centre of the tube of the axis of altitudes will mark the latitude; and, after the horizon is set, the quadrants of altitude will show on it the azimuth.

III. Mark the degrees of right ascension corresponding to the divided side of the meridian on the equator, keeping the globe always in the same position, as observed in II.

IV. Deduct or add, according to the difference shown by the globe, the degrees of right ascension of the zenith of the former place I, and of the second place III. This difference will be equal to longitude, if the apparent time of the first place was known, and if the right ascension of the zenith has been marked accordingly.

V. The same problem can likewise be solved, after observing four stars, while each pair of them lies in a plumb-line, as may be seen in Secs. 38 and 39.

Sec. 43.—I. Lunar distances, and occultations of stars by the moon, or when she comes before them so that they cannot be seen, and marking the hour, at the vessel, at the moment while such observations have been made, is, as is generally known, the principal manner by which the time shown by a chronometer is corrected, or the time of a place (from which longitude is counted) is ascertained. Such observations show the progress of the moon in her orbit at an observed time. This may, however, likewise be found, by observing when a plumb-line from a star lies at first in a tangential direction with the brim of the moon, and afterwards again on her opposite side, if the time has been marked when both took place, and if from this the time is known when the centre of the moon was in a plumb-line with the star. If no altitude can be taken, then the marking of the time when such a position of the moon's centre is known, or has been observed, will serve to find the moon's place tolerably well, if at least four such observations have been made, and if they have been applied to the globe,* to find the moon's place in her orbit.

II. The moon's mean motion in her orbit amounts, every 24 hours, to about 13 degrees, while she changes sometimes in the same interval of time from 11.5 to 15.5 degrees in right ascension, and from 1.5 to 3.5 degrees in declination. The mean motion of the moon during one minute, or the 1440th part of a day, is therefore only a little more than half a minute. Hence it results, that a fault in an observation which gives the moon's place about half a minute wrong in her orbit, will cause a fault of one minute in time, or of 15 minutes of an arc, or of 15 miles.

III. This proves what accuracy it requires to take lunar distances, so as not to be subjected to a great error in longitude. As the celestial objects are now (except in the zenith) never seen in the direction in which they lie, great care is to be taken in measuring distances, and in observing occultations of stars. The observed altitudes of celestial bodies require different corrections, and different altitudes give different distances of celestial bodies, and therefore the real distances of them from each other are always subjected to some correction. The altitudes, being the only means of correcting the found distances, are therefore to be taken with the greatest accuracy.

IV. Observations for lunar distances are always to be taken as follows:—1. the star's or sun's altitude; 2. the moon's altitude; 3. the lunar distance; 4. the moon's altitude; 5. the star's or sun's altitude; noticing always the time of a good watch, when each observation has been made. Three such sets of observations will, if their arithmetical mean be taken, and all possible accuracy obtained, give a tolerable good result; but it will be of service to observe, before these sets of observations, the time when a star is in a vertical line with each of the brims of the moon, and the same with another star, after these observations, and taking the arithmetical mean, when the moon's centre has been in a vertical line with each star. From this, the place of the moon may be found with greater accuracy, than in finding its place by a corresponding quadrant of altitude.

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* A plumb-line on the sea is best measured, as is well known, by a lead ball suspended on a fine wire of platina; while the ball, to prevent it from swinging, and to keep it steady, is kept in a vessel with water. Another instrument for this purpose is the artificial quicksilver horizon, on which swims a circular piece of plate glass, with a wire standing perpendicularly on the centre of the glass, in such a manner, that the wire always shows a vertical line.

V. The horary angle is requisite to be known in taking a lunar distance; and the time-piece used, to mark the time, is to be well regulated.

VI. It will always cause more difficulty, and more corrections, if a vessel has changed its position during the time while such observations have been made; it will, therefore, be better to stop the course of the vessel during such time.

Sec. 44.—To find the time of a place for which an ephemeris gives the moon's place and distances from the sun or a star, if the latitude and the time of the vessel are known, and after the requisite observations have been made. (Sec. 43, IV. Celestial globe.)

I. Mark the exact place of the sun or the star for the given hour on the globe, and fix a bar of a ray of altitude in the observed and corrected altitude, on the corresponding quadrant of altitudes.

II. Trace two places of the moon, according to the ephemeris, one for the next greater, and the other for the next smaller lunar distance from the sun or the star, and unite these two places by a line, representing a part of the moon's orbit. This line is to be divided into proper parts, to show the difference of time in sufficiently small parts between the given points.

III. Mark, by the other bar of a ray of altitude, on the other corresponding quadrant, the observed and corrected altitude of the moon.

IV. Bring the centre of the tube of the axis of altitudes over the given latitude on the meridian, and the corresponding ray of altitude over the sun or star.

V. If no fault has been committed, then will the horary angle of the sun or star on the instrument correspond with the hour of the vessel: if this be the case, then keep the globe in this position.

VI. Bring the ray of altitude of the moon over the traced part of its orbit. Where it, or the described almucantarath, intersects the orbit, the required hour of the place for which the ephemeris has been calculated is found.

VII. The observation of the vertical lines, from two stars to the moon's centre, are next to be applied to get the intersection of the moon's orbit, by the almucantarath, still more correct. 1. Mark the places of the stars with accuracy, and bring a quadrant of altitude over each of them with accuracy. 2. Mark the intersections of the divided side of the quadrant with the moon's orbit, when the quadrant is over the first and second star. 3. The interval of time shown on the traced orbit of the moon, between the intersection of the quadrants and that of the almucantarath with the orbit, must be the same as the observed intervals of time, if no fault has been committed.

Remark.—A globe, having 20 inches in diameter, and 6283 hundred parts of an inch in circumference, gives, for the moon's mean motion during 24 hours (as 360 : 13 = 6283 : 226.9), about two inches; consequently for her motion in half a minute, not quite one thousandth part of an inch; and this may, with a magnifying glass, very well be distinguished on glass paper. A larger globe will, of course give more, and a smaller globe less accuracy.

Sec. 45.—From observations of the time when the first brim of the moon, and when her other brim, and from this, when her centre lies in a vertical line with a star, the place of the moon in her orbit may likewise be ascertained. But sufficient accuracy can never be obtained by a single observation of this kind, and at least six of them are to be taken, and each to be applied to the globe, to find the corresponding intersection with the traced orbit of the moon, or her place for each time. If the intervals on the traced orbit correspond with the intervals of time, as measured, accuracy may be expected, if an arithmetical mean of all the results be taken.

Sec. 46.—I. From the known apparent time of a place where longitude is computed from, it may be found without further comment. (Sec. 2, IX.)

II. But it is to be mentioned, and is shown by turning a globe, that, 1. the altitudes of celestial bodies vary the most when they are about 90 degrees from the meridian. 2. Altitudes less than 20 degrees are generally subjected to great corrections, and do not give such a degree of accuracy as may be got by larger altitudes; therefore smaller altitudes ought never to be taken. 3. An almucantarath, described by an altitude of the moon, intersects her orbit more perpendicularly for the northern hemisphere; while her declination decreases, if east from the meridian; but her declination increases, if west from the meridian; and for the southern hemisphere, the declination increases, if east from the meridian; but her declination decreases, if west from the meridian.

Sec. 47.—A spherometer serves to verify all these calculations, and may be applied to the solving of all the given problems, and for verifying the answers found by the described operations with the globes; and it only requires a sufficient acquaintance with the instrument, to perform all operations necessary for solving spherical triangles with ease, accuracy, and dispatch.

Sec. 48.—As lunar distances serve for finding the time of a place for which an ephemeris has been calculated, so it may likewise be found by observed occultations of stars, if the time at the vessel is observed when a star enters the edge of the moon. The observations for this purpose are to be made in the same manner as mentioned in Sec. 43, and the operation is similar to that which has been shown in Sec. 44.

THE END.

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